INK JET PRINTER

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The invention relates to an ink jet printer that performs printing by ejecting ink from a print head and, more particularly, to an ink jet printer of ink tube supply type where ink to be ejected is supplied from an ink tank to a print head through an ink supply tube.

2. Description of Related Art

[0002] A conventionally known ink jet printer of ink tube supply type is disclosed in Japanese Laid-Open Patent Publication No. 59-73953.

[0003] Such an ink jet printer is designated by the numeral 620 in Fig. 25. Fig. 25 is a perspective view showing the ink jet printer 620 in schematic form. The ink jet printer 620 includes a print head unit 621, a platen roller 622, a carriage 623, an ink tank 624, an ink tube 625, a signal input line 626, and guide rods 627.

[0004] The print head unit 621 is equipped with a print head having ink nozzles from which ink is ejected to perform printing onto a paper sheet based on a signal sent via the signal input line 626. The print head unit 621 receives a supply of ink from the ink tank 624 via the ink tube 625. The print head unit 621 is installed on the carriage 623, which is attached to a belt. The belt is looped around a roller attached to a motor. Thus, when the motor runs, the belt is driven, which allows the carriage 623 with the print head unit 621 to move along the guide rods 27 for whatever distance the belt is driven.

[0005] The guide rods 627 are slidably inserted into the carriage 623 and support the carriage 623 for movement. Thus, the print head unit 621 installed on the carriage 623 can reciprocate in a direction parallel to the guide rods 627, that is, in both directions along the length of the platen roller 622.

[0006] In the ink jet printer of ink tube supply type, when the carriage equipped with the print head performs a printing operation while moving reciprocally, the ink in the ink tube undergoes acceleration, causing pressure waves that propagate in the ink toward the print head. The above-described printer is structured to absorb the pressure waves generated in the ink by placing an air-filled damper between the tubes.

[0007] On the other hand, to hold printing quality in the proper condition, the ink jet printer needs to maintain a constant state of ink to be ejected from the ink nozzles. To maintain the state of ink to be ejected, a meniscus (curved surface) is formed on the surface

of the ink at the end of each of the ink nozzles. As the meniscus is formed by, for example, causing a negative pressure in the ink to be supplied to the nozzles within a specified range, the pressure to supply the ink is kept constant, always producing the meniscus with the same shape. Thus, the ink to be ejected is maintained under a certain condition.

[0008] However, when the pressure waves propagating toward the print head are generated in the ink due to acceleration working on the ink, the negative pressure applied to the nozzles changes and the meniscuses are destroyed. Therefore, the ink to be ejected cannot be maintained under a constant condition, affecting printing quality.

[0009] Further, air may be introduced into the ink tube or the connecting portion between the damper and the ink tube, for example, when an ink tank is changed. When air is delivered by the ink flow to the ink nozzles through the ink tubes and other parts, the ink passage is closed by an air bubble when such an air bubble becomes large. Therefore, the ink jet printer is provided with a purging operation that is a process to recover the state of the ink to be ejected from the ink nozzles.

[0010] However, when discharging the air, ink is also discharged. This causes not only a wasting of ink but also a decrease in the efficiency of the air purging operation.

SUMMARY OF THE INVENTION

[0011] In the light of the foregoing, it is desirable to provide an ink jet printer of an ink tube supply type that addresses the foregoing drawbacks associated with ink jet printers described above.

[0012] One aspect of the invention involves an ink jet printer that includes a print head that has at least one ink nozzle and performs printing on a recording medium by ejecting ink from the ink nozzle; an ink tank that stores ink to be supplied to the print head; an ink passage that is connected to the ink tank to supply ink from the ink tank; an air chamber that is connected to the ink passage and the print head to store air generated in the ink passage; a purge device that discharges the air stored in the air chamber from the ink nozzle; and a filter member that divides the lower portion of the air chamber into a first chamber at the ink tank side and a second chamber at the ink head side. The air generated in the ink passage is stored in the top portion of the air chamber and the filter member passes ink therethrough when the print head performs printing.

[0013] The upper portion of the air chamber has less resistance to the ink flow than that of the filter member. The air stored in the air chamber is discharged when the purge device generates an ink flow that goes above the filter member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention will be described in greater detail with reference to embodiments thereof and the accompanying drawings wherein:

Fig. 1 is a developed side view of an ink jet printer according to one embodiment of the invention;

Fig. 2 is a sectional view of a print head unit of the invention;

Fig. 3 is a sectional view of a print head unit including an air trap unit, a purge device and feed rollers of a first embodiment of the invention;

Fig. 4 is a disassembled perspective view of the air trap unit of the first embodiment of the invention;

Figs. 5A–5F are perspective views showing the operation of the air trap unit of the first embodiment of the invention;

Fig. 6 is a sectional view of a print head unit of a second embodiment of the invention;

Fig. 7 is a sectional view of a print head unit of a third embodiment of the invention;

Fig. 8 is a sectional view of a print head unit of a fourth embodiment of the invention;

Fig. 9 is a disassembled perspective view of a print head including flexible printed circuits of the fourth embodiment of the invention;

Fig. 10 is a sectional view of a print head unit of a fifth embodiment of the invention;

Figs. 11A–11F are perspective views showing the operation of an air trap unit of the fifth embodiment of the invention;

Fig. 12 is a sectional view of a print head unit of a sixth embodiment of the invention;

Fig. 13 is a sectional view of a print head unit of a seventh embodiment of the invention;

Figs. 14A-14F are perspective views showing the operation of an air trap unit of the seventh embodiment of the invention;

Fig. 15 is a sectional view of a print head unit of an eighth embodiment of the invention;

Fig. 16 is a disassembled perspective view of an air trap unit of the eighth embodiment of the invention;

Figs. 17A-17F are perspective views showing the operation of the air trap unit of the eighth embodiment of the invention;

Figs. 18A–18C are enlarged sectional views of a film of the ninth embodiment of the invention;

Figs. 19A and 19B are enlarged sectional views of a ball valve of the tenth embodiment of the invention;

Fig. 20 is a sectional view of a print head unit of an eleventh embodiment of the invention;

Fig. 21 is a sectional view of a print head unit of the eleventh embodiment of the invention;

Fig. 22 is a disassembled perspective view of an air trap unit of the eleventh embodiment of the invention;

Figs. 23A-23F are perspective views showing the operation of the air trap unit of the eleventh embodiment of the invention;

Fig. 24 is a perspective view showing air flow in the air trap unit of the eleventh embodiment of the invention; and

Fig. 25 is a perspective view of a conventional ink jet printer.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0015] Fig. 1 is a side view of an ink jet printer 1 according to a first embodiment of the invention. The ink jet printer 1 includes a printer body 2 of flame-retardant plastic and substantially in the shape of a box, a print head unit 3, ink tanks 4a-4d, tubes 5a-5d interconnecting the print head unit 3 and the ink tanks 4a-4d, a purge device 6, and a guide rod 7.

[0016] The print head unit 3 is equipped with a plurality of print heads 15, each of which ejects ink onto a paper sheet PP for printing (Fig. 3). The print head unit 3 is in fluid communication with the ink tanks 4a-4d, provided at a lower part of the printer body 2, via the tubes 5a-5d and a joint member 12 (Fig. 2), and receives ink from the ink tanks 4a-4d. The print head unit 3 is installed on the carriage 3a, which is attached to a belt (not shown). The belt is looped around a roller (not shown) attached to a motor (not shown). When the motor runs, the belt is driven, which allows the carriage 3a with the print head unit 3 to move for the distance the belt is driven.

[0017] The guide rod 7 is slidably inserted into the carriage 3a to support the carriage 3a so that it can move in direction A orthogonal to a sheet feed direction. The print head unit 3 on the carriage 3a moves reciprocally in a direction parallel to the guide rod 7, that is, in direction A of the length of the printer body 2.

[0018] The ink tank 4 is designed to store ink supplied to the print head unit 3, and is disposed below the print head unit 3. The ink tank 4 comprises a plurality of sub-ink tanks and, in this embodiment, four ink tanks 4a-4d to store black, yellow, cyan, and magenta inks

in the identified order from left to right, as shown in Fig. 1. One end of each of the tubes 5a–5d is attached to the corresponding ink tank 4a-4d so as to supply the respective color ink of black, yellow, cyan and magenta to the print head unit 3. The other end of each of the tubes 5a-5d is connected to a print head 15 for the corresponding color ink. The respective color inks are ejected from the print heads 15, enabling full-color printing on a paper sheet PP.

[0019] The purge device 6, that performs the purging operation, is disposed on a left end of the printer body 2. The purging operation is a process to recover the state of the ink to be ejected from the print heads 15. The purge device 6 is provided with a suction cap 6a that can hermetically seal the ink nozzles of the print heads 15, a wiper 6b that wipes the surface of the ink nozzles, and a pump (not shown) that sucks ink from the suction cap 6a via a discharge tube 6c. The purge device 6 may be designed to discharge the ink from the print heads 15 by applying a positive pressure to the ink from the ink tank 4.

[0020] During the purging operation, the motor is driven to move the print head unit 3, equipped with the print heads 15, to the left of the ink jet printer 1 as shown in Fig. 1. The ink nozzles of the print heads 15 are hermetically sealed by the suction cap 6a. Then, the pump is actuated and air bubbles and solidified ink are sucked and discharged from the tube 6c. The wiper 6b wipes the surface of the print heads 15, so that the state of the ink nozzles is recovered.

[0021] A control circuit board (not shown) mounting a CPU, a ROM, a RAM and other control devices is provided inside the printer body 2. The control circuit board controls the ink jet printer 1 according to control programs related to operation of the ink jet printer 1. The purging operation by the purge device 6 is also controlled by the control circuit board.

[0022] The print head unit 3 will be described in detail with reference to Figs. 2 and 3. As shown in Fig. 2, the carriage 3a is provided with a body 3b for accommodating an air trap unit 11 and the joint member 12. The air trap unit 11 is designed to trap air bubbles included in the ink supplied from the ink tanks 4a-4d to the print heads 15 and prevent such air bubbles from flowing into the print heads 15. The air trap unit 11 is divided by partitions 11h into air trap chambers 30-33 so that each chamber, containing a different color ink, is linked to a print head of the corresponding color ink. The four air trap chambers 30-33 are made into one body so that the number of parts is decreased.

[0023] The air trap chambers 30-33 are provided with intakes 11g at the bottom, each intake 11g connecting the joint member 12 and an appropriate one of the air trap chambers 30-33.

[0024] The joint member 12 is a structural component to connect tubes 5a-5d, each supplying ink from a corresponding ink tank 4a-4d to the air trap chambers 30-33, and is formed into one body by injection molding. The joint member 12 is made of thermal plastic elastomer or TPE. TPE has characteristics between rubber and plastic or characteristics of both of them, and shows elastic characteristics of rubber at normal temperatures. This elasticity absorbs displacement errors made when the air trap chambers 30-33 are connected or errors in the size of the air trap chambers 30-33. On the other hand, TPE is plasticized at high temperatures. Therefore, forming by a synthetic resin forming machine becomes easier. Olefinic PTE, butyl PTE, and silicon PTE can be used for the joint member 12. In this embodiment, olefinic PTE is preferrable when air penetrability, moldability, cost effectiveness and environmental issues are considered.

[0025] An outer profile of the joint member 12 is in a cubic shape, and the joint member 12 is provided with four connecting ports 12a-12d corresponding to the air trap chambers 30-33, respectively, and four ink ports 12e-12h corresponding to the tubes 5a-5d, respectively. The connecting ports 11g are connected to the connecting ports 12a-12d. The ink ports 12e-12h are of a cylindrical shape. In order to keep the joint member 12 in balance, the ink ports 12e, 12f are provided on one side of the joint member while the ink ports 12g, 12h are provided on the other side of the joint member 12. The ink ports 12e-12h are connected to the ink tubes 5a-5d, respectively.

[0026] The connecting ports 12a-12d, connected to the air trap chambers 30–33, and the ink ports 12e-12h, connected to the ink tubes 5a-5d, communicate with each other through the joint member 12, respectively, so that ink is supplied respectively to the air trap chambers 30-33 from the ink tanks 4a-4d through the ink tubes 5a-5d and the joint member 12.

[0027] Referring to Fig. 3, paper feed rollers 16a-16d are provided for the print head unit 3 for feeding a paper sheet PP onto which the print head unit 3 prints. Two paper feed rollers 16a, 16b are placed at the bottom portion of the print head unit 3 and the other two paper feed rollers 16c, 16d are placed at the top portion of the print head unit 3. The paper feed rollers 16a-16d are controlled by the signals from the control circuit board of the ink jet printer 1 to feed a paper sheet PP in the direction perpendicular to the moving direction A of the print heads 15, that is the vertical direction B. The paper feed line of a paper sheet PP is indicated by a dot line in Fig. 3.

[0028] The print head unit 3 is placed at a position facing and parallel to the paper feed line along which the paper sheet PP is carried by the paper feed rollers 16a-16d. The

print head unit 3 is provided, on the paper sheet feeding side, with a plurality of print heads 15 corresponding to the air trap chambers 30-33, respectively.

[0029] The print heads 15 are provided with a plurality of ink nozzles facing the paper sheet PP and ink is delivered to ink channels from each air trap chamber 30-33 so that ink is ejected from the ink nozzles in accordance with the deformation of the actuator 15a.

[0030] The print heads 15 are supported by the body 3b and connected with the air trap chambers 30-33 through connecting passages 14. Each air trap chamber 30-33 is divided into a first chamber 11a and a second chamber 11b by a first filter 13a and extends vertically along the body 3b, as shown in Fig. 3. The first and second chambers 11a, 11b are placed vertically in the position perpendicular to the moving direction of the carriage 3a. Accordingly, the first chamber 11a is placed on the side of the ink tank 4 and the second chamber 11b is placed on the side of the print heads 15.

[0031] The first chamber 11a is separated by the first filter 13a and is located on the side of the ink tank 4, upstream of the ink passage. The first filter 13a separates the two chambers 11a, 11b, and opening 13e of the first filter 13a is left open. The ink supplied from the ink tanks 4a-4d through the tubes 5a-5d is introduced into the proper first chamber 11a through the joint member 12 connected to the bottom portion of the first chamber 11a. The ink introduced into the first chamber 11a is supplied to the second chamber 11b through the first filter 13a and the opening 13e provided at the upper position of the first filter 13a, as shown in Figs. 5A-5F.

[0032] A thermistor 18a is provided in the first chamber 11a. The thermistor 18a is hung from the top of the first chamber 11a to detect the ink level in the first chamber 11a. The thermistor 18a has a pair of positive and negative electrodes and electricity is supplied thereto continuously. When the thermistor 18a is immersed in the ink, the temperature of the thermistor 18a does not rise. When the thermistor 18a is not covered by the ink in the first chamber 11a, the temperature goes up. The resistance of the thermistor 18a changes when the temperature changes. The thermistor 18a is connected to a signal line of the control circuit provided in the printer body 2. When a resistance change is detected from the signal sent to the control circuit, it is determined that air trapped in the air trap chamber 30-33 has exceeded a predetermined volume. The control circuit sends out a signal to the purge device 6. The purge device 6 conducts a purging operation to remove air trapped in the air trap chamber 30-33.

[0033] The second chamber 11b is separated by the first filter 13a and is located on the side of the print heads 15, downstream of the ink passage. The second chamber 11b is

provided with a guide nozzle 11j at the bottom portion. The guide nozzle 11j is connected to the ink nozzle through the passage 14. The ink is supplied from the second chamber 11b to the corresponding print head 15. Accordingly, the length of the print head unit is reduced by the omission of connecting tubes.

[0034] The volume of the second chamber 11b is set to be smaller than that of the first chamber 11a. In this embodiment, the volume of the second chamber 11b is set at about half of that of the first chamber 11a. When air trapped in each air trap chamber 30-33 is sucked by the purging operation, ink contained in the second chamber 11b is discharged. In this embodiment, because the volume of the second chamber 11b is smaller than that of the first chamber 11a, the amount of discharged ink becomes smaller. Further, pressure required to suck ink, that is, to suck air from the second chamber 11b is reduced.

[0035] An inner wall of the second chamber 11b is formed by crystalline resin having high wettability to ink or the surface of the inner wall is finished to improve wettability to ink. Thus, the inner wall easily gets wet with ink. Because it is difficult for ink to stay at the inner wall, air trapped in the second chamber 11b is discharged easily and quickly.

[0036] The first filter 13a, as described above, divides the lower portion of each air trap chamber 30-33 into the first and second chambers 11a, 11b at such a position that the volume of the second chamber 11b is smaller than that of the first chamber 11a or about half of the first chamber 11a. The first filter 13a extends vertically, parallel to the body 3b of the print head unit 3. The face of the first filter 13a is placed parallel to the moving direction A of the carriage 3a and the longer side of the first filter 13a is also placed parallel to the moving direction A of the carriage 3a so the height, in the vertical direction B, of the filter element in each air trap chamber 30-33 is greater than the width. Because the first filter 13a is placed parallel to the moving direction A of the carriage 3a, the print head of the embodiment becomes smaller in size and length in the orthogonal direction to the moving direction of the carriage 3a than a print head that has a first filter placed perpendicular to the moving direction of the carriage.

[0037] The first filter 13a is a meshed net made of stainless steel having openings of the diameter at 16 μm in order to prevent air generated in the ink passage from passing through the first filter 13a.

[0038] The vertical dimension (in direction B) of the first filter 13a is shorter than the vertical inside dimension of each air trap chamber 30-33 to form the opening 13e. The opening 13e allows ink to communicate between the first and second chambers 11a, 11b with

less resistance. The first filter 13a continues to the opposed inner walls extending in the width direction (direction A) of each air trap chamber 30-33 to prevent air introduced into the first chamber 11a from entering into the second chamber 11b. Each air trap chamber 30-33 and the first filter 13a are placed in the vertical direction so that air introduced into the air trap chamber 30-33 goes up along the first chamber 11a and is trapped at the top portion of the first chamber 11a because the first filter 13a does not allow air to go through its openings. Because the first filter 13a is made of stainless steel which has wettability to ink, it is difficult for air to stay at the first filter 13a but it is easy for air to move up to the first chamber 11a.

[0039] A passage filter 13b is provided at the passage 14 which connects the guide nozzle 11j of each air trap chamber 30-33 and the corresponding print head 15 in order to catch dirt contained in the ink before supply to the print heads 15. The passage filter 13b is made to cover the passage 14 and is thermally welded to the passage 14. The passage filter 13b has openings small enough to catch dirt but large enough to pass ink and air during purging.

[0040] A driver circuit board 17a is provided at the top portion of the body 3a of the print head unit 3. The driver circuit board 17a is mounted on the flexible printed circuit board 17c. The driver circuit board 17a is controlled by the control circuit mounted on the printer body 2. The driver circuit board 17a changes serial signals sent by the control circuit into parallel signals corresponding to the actuator 15a in order to control the actuator 15a. The flexible printed circuit board 17c is provided with two thin non-conductive flexible films and a conductive layer providing wiring patterns placed between the two films. One end portion of the flexible printed circuit board 17c is provided with terminals connected to the actuator 15a and the earth. The other end portion of the flexible printed circuit board 17c is provided with terminals connected to an interface board 17b described below.

[0041] An interface board 17b is placed adjacent to the carriage 3a in the body 3b of the print head unit 3. The interface board 17b is connected to a terminal portion of the flexible print board 17c and is provided with a connector which connects signal wires from the control circuit with the driver circuit board 17a and a noise reduction circuit.

[0042] Referring to Fig. 4, the air trap unit 11 and the joint member 12 are further described. The air trap unit 11 comprises three parts 11d-11f. Each part 11d-11f is formed to have four air trap chambers 30-33, corresponding to the four ink tubes 5a-5d. Each part 11d-11f is made of a thermoplastic resin considering physical properties, such as moldability, resistance to solvents, resistance to contamination, chip resistance, and wettability to ink.

[0043] The part 11d is provided with four first chambers 11a divided by the partitions 11h as shown in Fig. 2. Each chamber 11a is box shaped and has an opening through which the first filter 13a is attached. The part 11d is provided at the bottom with intakes, or connecting portions, 11g to be connected to the joint member 12. The connecting portions 11g are cylindrical projections corresponding to the ink tubes 5a-5d. The joint member 12 is provided with connecting ports 12a-12d that communicate with the ink tubes 5a-5d, respectively. The connecting ports 12a-12d are connected to the connecting portions 11g so that ink is introduced from the ink tank 4 to the air trap chambers 30-33 through the ink tubes 5a-5d.

[0044] The first filter 13a is fixed by thermal fusion to the part 11e to operate as the first filter 13a for each air trap chamber 30-33. The face of the first filter 13a is placed parallel to the moving direction of the carriage 3a and the longer side of the first filter 13a is also parallel to the moving direction of the carriage 3a. In this embodiment, one first filter 13a provides four filter portions for the air trap chambers 30-33 so that the first filter 13a for the four air trap chambers 30-33 are made at a time by thermal fusion of the first filter 13a to the part 11e.

[0045] The length of the first filter 13a corresponds to the total width of series of the four air trap chambers 30-33 in addition to the fusion areas on both sides. The height of the first filter 13a corresponds to a height to cover a predetermined lower area of the air trap chambers 30-33 in addition to the fusion area. The first filter 13a having such a size is fixed to the part 11e by thermal fusion so as to provide openings at the upper portion of the part 11e constituting the second chambers. Thus, the first filter 13a is placed in such a position as to divide the air trap chambers 30-33 into the first chambers 11a and the second chambers 11b.

[0046] The part 11e has four openings to define the four second chambers 11b. One side of the part 11e is fixed to the first filter 13a and the other side of the part 11e is fixed to the part 11f by ultrasonic fusion in order to form the four second chambers 11b. The part 11f has four recessed portions corresponding to the four openings of the part 11e. The part 11f is provided with conduits formed below the recessed portions to form the guide nozzles 11j. End terminals of the conduits go through the part 11f to the rear side so that the guide nozzles 11j are connected to the passages 14. The second chamber 11b is directly connected to the corresponding print head 15. Accordingly, the length of the print head 15 which is perpendicular to the moving direction of the carriage 3a is reduced by the omission of connecting tubes.

[0047] To make the air trap unit 11 from the parts 11d-11f, first the first filter 13a is fixed to the part 11e by thermal fusion. The part 11f is fixed to the part 11e by ultrasonic fusion. The part 11d is fixed to the part 11e from the side of the first filter 13a by ultrasonic fusion. The fabrication of the air trap unit 11 becomes simpler than making each air trap chamber one by one. It is also easy to manage the process because the number of parts is less. Further it is easy to fabricate because each part becomes bigger.

[0048] Referring to Figs. 5A-5F, ink flow patterns and the condition of the trapped air will be described. Fig. 5A shows an initial condition of an air trap chamber 30-33 of the air trap unit 11 immediately after the purging operation. In Fig. 5A, as ink is consumed at the print head 15, ink supplied from the ink tank 4 to the first chamber 11a goes into the second chamber 11b over the first filter 13a, i.e., through the opening 13e where the first filter 13a is not provided. The opening 13e has less resistance to the ink flow than the first filter 13a thereby allowing such an ink flow.

[0049] In Fig. 5B, when a small amount of air enters the first chamber 11a of the air trap chamber 30-33, air is unlikely to stick to the first filter 13a because of the good ink wettability of the first filter 13a. In addition, because the air trap chamber 30-33 is placed in the vertical direction, air rises by its own buoyancy along the ink current flow. Further, because the openings of the first filter 13a are smaller in size than the air bubbles, the air bubbles do not pass through the openings of the filter 13a, but rise along the ink current flow.

[0050] The inner wall of the first chamber 11a is formed with a material having less ink wettability as compared to the inner wall of the second chamber 11b, so that air stays in the first chamber 11a rather than in the second chamber 11b. When the volume of air trapped in the chambers 11a, 11b is relatively small, the opening 13e between the first chamber 11a and the second chamber 11b is not blocked by the trapped air. Ink supplied into the first chamber 11a flows into the second chamber 11b through the opening 13e. The speed of the ink flow directed to the print head 15 or the suction force of the ink during printing is not fast enough to push the trapped air out from the chambers 11a, 11b.

[0051] In Fig. 5C the trapped air becomes great enough to block the opening 13e between the first and second chambers 11a, 11b. Ink supplied to the first chamber 11a is blocked from going into the second chamber 11b through the opening 13e. Once the opening 13e is closed by the trapped air, ink goes through the first filter 13a as shown in Fig. 5C.

[0052] In Fig. 5D, the volume of the trapped air becomes larger and pushes the level of the ink surface in the chambers 11a, 11b down. The area of the first filter 13a and its

openings are appropriately set to pass a sufficient ink supply even when the ink level falls to a predetermined level.

[0053] In Fig. 5E, the volume of the trapped air becomes large enough to fill the second chamber 11b. In this state, no ink is supplied to the print head 15.

[0054] In Fig. 5F, the purging operation is conducted by the purge device 6 so that the trapped air is discharged. During the purging operation, because a strong suction force is applied to the second chamber 11b, a resistance to the ink flow going through the first filter 13a becomes very large. Thus a strong ink flow going through the opening 13e between the first and second chambers 11a, 11b is generated to discharge the trapped air in the air trap chamber 30-33 to the outside. The first and second chambers 11a, 11b are refilled with ink and return to the initial condition shown in Fig. 5A.

[0055] In this embodiment, the thermistor 18a is provided to cause the purging operation when the level of ink in the first chamber 11a reaches a predetermined level. As described, the ink has a viscosity of 1-10 cps and a surface tension at 30-50 mN/m. The openings of the first filter 13a are about 16 μm.

[0056] As described above, because the first filter 13a functions as a dam in the air trap chambers 30-33, air generated in the ink passage, such as the ink tube 5a-5d and the joint member 12, is trapped in the air trap chamber 30-33. The print head 15 can operate for a longer time and the number of purging operations is reduced. The purging operation is conducted when the thermistor 18a indicates the need for the purging operation. Further the length of the first filter 13a is reduced because the face of the first filter 13a is placed parallel to the moving direction A of the carriage 3a and the longer side of the first filter 13a is also placed in the moving direction A of the carriage 3a so the filter height is in the vertical direction B for each air trap chamber 30-33.

[0057] In the above embodiment, the size of the openings of the first filter 13a is about 16 μm, however, the first filter 13a is not for catching dirt in the ink but is to act as a dam to separate the air trap unit 11. Therefore, the size of openings can be set under about 100 μm.

[0058] The first filter 13a can be made of a resin having good wettability instead of stainless steel. Resin is easier to machine and less expensive than stainless steel.

[0059] The tubes 5a-5d are made of a resin having flexibility. However, in order to reduce the permeability to air, the tubes 5a-5d can be covered by a metal film with low permeability to air.

[0060] Referring to Fig. 6, a second embodiment of the invention will be described. However, the parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted. In this embodiment, a second filter 13c is provided on the first filter 13a.

[0061] The second filter 13c has the same width as that of the first filter 13a. The height of the second filter 13c is the length from the top of the first filter 13a to the top or ceiling of each air trap chamber 30-33. The second filter 13c extends from the top of the first filter 13a and the other end of the second filter 13c is held between the part 11d and part 11e. The second filter 13c extends vertically from the first filter 13a and contacts the ceiling of each air trap chamber 30-33. In other words, the first filter 13a and the second filter 13c are placed in the same line.

[0062] Ink comes into each air trap chamber 30-33 and passes through the first filter 13a or the second filter 13c. The first and second filters 13a, 13c catch dirt in the ink. With this arrangement, the passage filter 13b can be omitted. The openings of the mesh of the second filter 13c are larger in diameter than the first filter 13a, and the second filter 13c provides less resistance to the ink flow than that of the first filter 13a.

[0063] A third embodiment of the invention will be described with reference to Fig. 7. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted. In this embodiment, an optical sensor 18b replaces the thermistor 18a used to detect the level of ink in each air trap chamber 30-33 in the first embodiment.

[0064] Referring to Fig. 7, the optical sensor 18b is placed on the rear side of the first chamber 11a of the air trap unit 11 in the body 3b of the print head unit 3. The optical sensor 18b comprises a light source and a detector to detect a reflected light emitted from the light source. The body 11d of the first chamber 11a of the air trap unit 11 is made of a transparent material so that the light emitted from the light source of the optical sensor 18b passes through. Because the amount of the light reflected is different when the level of ink is above the optical sensor 18b than when the level is lower than the optical sensor 18b, the sensor 18b detects the level of the ink surface in the air trap unit 11.

[0065] Because the optical sensor is placed outside the ink, the optical sensor has a longer life. When each air trap chamber 30–33 is provided with an optical sensor, the purging operation is conducted based on the sensor signal for each air trap chamber 30-33. When the ink jet printer prints in single color, an optical sensor can be arranged such that a detector is placed facing a light source.

[0066] A fourth embodiment of the invention will be described with reference to Figs. 8 and 9. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted.

[0067] Referring to Fig. 8, the driver circuit board 17a and the interface board 17b are mounted on the flexible printed circuit board 17c. The interface board 17b is provided with a connector 17e and a noise reduction circuit 17f. The connector 17e is connected to a second flexible printed circuit board 17d. The second flexible printed circuit board 17d is made of thin films, similarly to the first flexible printed circuit board 17d. The second flexible printed circuit board 17d in the printer body 2 delivers various signals, such as serial image data, a clock signal, a latch signal, and a strobe signal sent from the control circuit board (not shown), mounted with a CPU, ROM, RAM and other elements, to the interface board 17b.

[0068] Referring to Fig. 9, which is simplified by omitting the walls between air trap chambers 30-33, as well as other features of the air trap chambers 30-33 shown in Fig. 8, a body 3b of the print unit 3 is formed into a box shape and the air trap unit 11 and the joint member 12 are incorporated into the body 3b. The print heads 15 are fixed to the body 3b facing toward the print paper. The interface board 17b is fixed to the body 3b so as to cover the air trap unit 11. In other words, the interface board 17b is placed on one side of the body 3b and the print heads 15 are placed on the other side of the body 3b, parallel to the interface board 17b in order to sandwich the air trap unit 11 in between. The first flexible printed circuit board 17c is connected to the actuator 15a on the side of the print heads 15. The first flexible printed circuit board 17c goes over the body 3b and is connected to the interface board 17b. The body 3b is provided with the print heads 15, the air trap unit 11, the interface board 17b, and other parts, and is mounted onto the carriage 3a.

[0069] In this embodiment, the interface board 17b and the body 3b of the print head unit 3 are formed as one unit to cover the air trap unit 11. Accordingly, the print head unit 3 becomes smaller in size and thinner in depth.

[0070] In this embodiment, although the driver circuit 17a is mounted on the first flexible printed circuit board 17c, the driver circuit 17a can be placed on the interface board 17b and connected to the first flexible printed circuit board 17c.

[0071] A fifth embodiment of the invention will be described with reference to Figs. 10 and 11. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted.

[0072] Referring to Fig. 10, at the upper portion of the first chamber 11a, an air chamber 11a1 is provided to trap and hold a certain amount of air at all times. The air chamber 11a1 is located at a higher position, or is recessed, than the remainder of the ceiling over the first and second chambers 11a, 11b such that air bubbles rise into the air chamber 11a1 in the first chamber 11a. The air chamber 11a1 is located at the higher position than that of the ink flow along the ceiling of the chambers 11a, 11b and above the first filter 13a during the purging operation. The air trapped in the air chamber 11a1 remains even during the purging operation by the purge device 6. The air chamber 11a1 is also located at a position extending from an ink inlet 11i. Most of pressure waves generated in the ink passage propagate along the ink flow formed in the ink passage. The pressure waves go into the air trapped in the air chamber 11a1 and the trapped air absorbs the pressure waves, thereby preventing the pressure waves from reaching the print head 15. In order to absorb the pressure waves generated in the ink passage, the volume of the air chamber 11a1 is less than 0.3 cc. In this embodiment, the volume of the first chamber 11a is set at between 0.2-0.4 cc, the volume of the second chamber 11b is set at between 0.03-0.1 cc and the volume of the air chamber 11a1 is set at between 0.05-0.1 cc.

[0073] Referring to Figs. 11A-11F, the pressure wave propagation pattern, the ink flow pattern, and the condition of trapped air will be described. Fig. 11A shows an initial state of the air trap unit 11 immediately after the purging operation. Even though the first chamber 11a is filled with ink, air is trapped and held in the air chamber 11a1.

[0074] As the ink is consumed at the print heads 15, the ink supplied from the ink tank 4 to the first chamber 11a goes into the second chamber 11b over the first filter 13a or through the opening 13e where the first filter 13a is not provided. The opening 13e that has less resistance to the ink flow than the first filter 13a thereby allowing such ink flow.

[0075] The pressure waves generated in the ink passage due to speed changes of the carriage 3a propagate from the ink inlet 11i to the first chamber 11a and upward in the first chamber 11a. The air chamber 11a1 is placed in the propagation direction of the pressure waves, so that the pressure waves go into the air trapped in the air chamber 11a1.

[0076] In Fig. 11B, when a small amount of air enters the first chamber 11a of each air trap chamber 30-33, air is unlikely to stick to the first filter 13a because of good ink wettability of the first filter 13a and the openings in the first filter 13a are smaller in size than the air bubbles. Because each air trap chamber 30-33 extends vertically, air rises by its buoyancy along the ink flow and merges into the air trapped in the air chamber 11a1.

[0077] The inner wall of the first chamber 11a is formed with a material having less ink wettability as compared with the inner wall of the second chamber 11b, so that air stays in the first chamber 11a rather than in the second chamber 11b. When the volume of air trapped in the chambers 11a, 11b is relatively small, the opening 13e between the first chamber 11a and the second chamber 11b is not blocked by the trapped air. The ink supplied into the first chamber 11a flows into the second chamber 11b through the opening 13e. The pressure waves generated in the ink passage propagate in the ink and strike the merged air in the air chamber 11a1 and the chambers 11a, 11b. The speed of the ink flow directed to the print head 15 or the suction force of the ink is not fast enough to push the trapped air out from the chambers 11a, 11b, so that the trapped air in the chambers 11a, 11b absorb the pressure waves efficiently.

[0078] In Fig. 11C, the trapped air becomes large enough to block the opening 13e between the first and second chambers 11a, 11b. The ink supplied to the first chamber 11a is blocked and cannot go into the second chamber 11b through the opening 13e. Once the opening 13e is blocked by the trapped air, ink starts passing through the first filter 13a, as shown in Fig. 11C.

[0079] In Fig. 11D, the volume of the trapped air becomes great enough to push down the ink level in the chambers 11a, 11b. The area of the first filter 13a and its openings are appropriately set to ensure a sufficient ink supply even when the ink level falls to a predetermined level.

[0080] In Fig. 11E, the volume of the trapped air becomes large enough to fill out the second chamber 11b. In this state, no ink is supplied to the print head 15.

[0081] In Fig. 11F, the purging operation is conducted by the purge device 6 so that the trapped air is discharged. During the purging operation, because a strong suction force is applied to the second chamber 11b, resistance to the ink flow going through the first filter 13a becomes very high. Thus, a strong ink flow going through the opening 13e between the first and second chambers 11a, 11b is generated to discharge the trapped air in the air trap chambers 30-33 to the outside. The first and second chambers 11a, 11b are refilled with ink and return to the initial state shown in Fig. 11A. The air stays in the air chamber 11a1 during the purging operation because the air chamber 11a1 is located above the ink flow generated by the purging operation.

[0082] Thus, the pressure waves generated in the ink passage are absorbed by the air trapped in the air chamber 11a1 and prevented from reaching the print head 15. As a result, the meniscus formed at each nozzle is maintained properly.

[0083] A sixth embodiment of the invention will be described with reference to Fig. 12. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted.

[0084] Referring to Fig. 12, the air trap unit 11 includes an air chamber 11a2 provided along the entire ceiling of the first chamber 11a. The air chamber 11a2 has a bigger capacity than that of the air chamber 11a1 in the previously described embodiment. The air chamber 11a2 occupies a wider area of the first chamber 11a to absorb the pressure waves propagating in the ink passage.

[0085] A seventh embodiment of the invention will be described with reference to Figs. 13 and 14. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted.

[0086] Referring to Fig. 13, the print heads 15 are supported by the body 3b and connected to the air trap chambers 30-33 through the connecting passages 14. Each air trap chamber 30–33 is divided into three chambers which extend vertically, parallel to the body 3, as shown in Fig. 13. A second chamber 11b is disposed on the side of the print head 15, a first chamber 11a is disposed upstream of the ink passage from the second chamber 11b, and a third chamber 11c is disposed upstream from the first chamber 11a. Air, which has not been removed by the purging operation, is trapped at all times at an upper portion of the first, second, and third chambers 11a-11c.

[0087] The third chamber 11c is disposed most upstream of the ink passage in each air trap chamber 30-33 and has, at its bottom, an ink inlet 11c1. The joint member 12 is directly connected to the ink inlet 11c1 so that ink is supplied from the ink tank 4. The third chamber 11c and the first chamber 11a are separated by a guide wall 311d1. The guide wall 311d1 extends vertically from the bottom of third chamber 11c.

[0088] More specifically, the vertical dimension (in direction B) of the guide wall 311d1 is smaller than the vertical inside dimension of each air trap chamber 30-33. Accordingly, the guide wall 311d1 is not formed at an upper portion of each air trap chamber 30-33 and an empty space, or gap, 311d2 is formed there. Through the empty space 311d2, the third chamber 11c communicates with the first chamber 11a. Air is trapped in this empty space 311d2 at all times. The guide wall 311d1 is designed to be higher than the first filter 13a. The guide wall 311d1 continues to the opposed inner walls, extending in the width direction (direction A), of each air trap chamber 30-33.

[0089] The guide wall 311d1 is made of such a material and formed into such a shape as to inhibit the passage of ink and air therethrough. Thus, ink and air flowing from the

ink inlet 11c1 into the third chamber 11c cannot pass though the guide wall 311d1 to the first chamber 11a and, instead, moves upwardly along the guide wall 311d1 and strikes the air trapped at an upper portion of the third chamber 11c. After that, the ink passes through the trapped air and flows into the first chamber 11a.

[0090] Because the guide wall 311d1 is made of a material having high wettability to ink, the air is unlikely to stay at the guide wall 311d1. The air flowing into the third chamber 11c is guided upwardly along the guide wall 311d1 and is trapped at the upper portion of the third chamber 11c.

[0091] In addition, pressure waves transferred in the ink through the tube 5a-5d move upwardly along the guide wall 311d1 and strike the air trapped at the upper portion of the third chamber 11c. As a result, the pressure waves are absorbed by the air. As described above, by trapping the air in the middle of the ink passage defined by the third chamber 11c and the first chamber 11a, pressure waves generated in the tube 5a-5d, due to speed changes of the carriage 3a during printing, can be reliably absorbed by the air trapped in each air trap chamber 30-33. Thus, the pressure waves are prevented from propagating to each print head 15.

[0092] Because the guide wall 311d1 is disposed higher than the first filter 13a, the ink passage from the first chamber 11a to the second chamber 11b is formed above the first filter 13a. The ink flow pattern (ink passage) in each air trap chamber 30-33 will be described later with reference to Figs. 14A-14F.

[0093] The first chamber 11a is defined by the guide wall 311d1 and the first filter 13a. The first chamber 11a and the second chamber 11b are not separated completely by the first filter 13a and communicates with each other through the upper opening 13e. The third chamber 11c communicates with the first and second chambers 11a, 11b through the opening, or gap, 311d2 above the guide wall 311d1. The ink supplied from the third chamber 11c to the first chamber 11a is supplied to the second chamber through the first filter 13a and the upper opening 13e.

[0094] The first chamber 11a is provided with a first thermistor 18a and a second thermistor 18b. The first thermistor 18a is hung at a first predetermined position from the top of the first chamber 11a to detect the ink level in the first chamber 11a. The first thermistor 18a has a pair of positive and negative electrodes and electricity is supplied thererto continuously. When the thermistor 18a is immersed in the ink, the temperature of the thermistor 18a does not rise greatly. When the thermistor 18a is exposed from the ink in the first chamber 11a, the temperature rises greatly. The resistance of the thermistor 18a changes

when the temperature changes. Thus, the ink level can be detected upon detection of a resistance change of the thermistor 18a. The thermistor 18a is connected to a signal line of the control circuit provided in the printer body 2. When a resistance change is detected from the signal sent to the control circuit, it is decided that air trapped in the air trap chamber 30-33 has exceeded a predetermined volume. The control circuit sends out a signal to the purge device 6. The purge device 6 conducts the purging operation to remove the air trapped in the air trap chamber 30-33.

[0095] The second thermistor 18b is hung at a second predetermined position higher than the first thermistor 18a (as high as the top of the guide wall 311d1). The second thermistor 18b has the same structure as the first thermistor 18a. When the ink is supplied to the second predetermined position after the purging operation by the purge device 6, the second thermistor 18b detects the ink. A detection signal is sent, upon detection of a resistance change, from the second thermistor 18b to the control circuit, as with the first thermistor 18a.

[0096] A rise in the ink level in the first chamber 11a after the purging operation by the purge device 6 indicates a decrease in the volume of air trapped in the air trap chamber 30-33. When a resistance change of the thermistor 18b is detected from the signal sent to the control circuit, it is decided that the volume of ink in the air trap chamber 30-33 has exceeded a predetermined volume. The control circuit sends out a signal to the purge device 6 to stop the purging operation. The purge device 6 stops purging and a predetermined volume of air is left in the air trap chamber 30-33. Thus, the air remains at the upper portion of the air trap chamber 30-33 (at the opening above the guide wall 311d1 between the first chamber 11a and the third chamber 11c) so as to absorb the pressure waves generated in the ink passage.

[0097] Referring to Figs. 14A-14F, the pressure wave propagation pattern, the ink flow pattern, and the air trapped condition in the air trap unit 11 will be described. Figs. 14A-14F are vertical sectional views of the air trap chamber 30-33 of the print head unit 3 and show the air trap function in schematic form. Fig. 14A shows an initial state immediately after the purging operation where the air trap chamber 30-33 is filled with ink to the predetermined level. Even in the initial state shown in FIG. 14A, air is left at the upper portion of the air trap chamber 30-33 by the functioning of the thermistor 18b.

[0098] In this case, the ink flow pattern is produced in the air trap chamber 30-33 as described below. As the print head 15 ejects ink, the ink levels in the first and second chambers 11a, 11b fall, and the pressure is reduced in the first and second chambers 11a, 11b. As a result, ink in the ink tank 4, tube 5a-5d, joint member 12, and third chamber 11c is

drawn upwardly into the air trap chamber 30-33 along the guide wall 311d1 and is supplied, over the top end of the guide wall 311d1, to the first chamber 11a. Then, the ink flows, over the top end of the first filter 13a, into the second chamber 11b because the opening 13e (formed above the first filter 13a) between the first and second chambers 11a, 11b has less resistance to the ink flow than the first filter 13a. The ink flowing into the second chamber 11b is supplied to the corresponding print head 15 through the guide nozzle 11j.

[0099] Pressure waves generated in the tube 5a-5d due to speed changes of the carriage 3a propagate to the third chamber 11c through the ink inlet 11c1. Then, the pressure waves propagate along the guide wall 311d1 and strike the air trapped at the upper portion of the air trap chamber 30-33, thereby being absorbed by the air.

[0100] Fig. 14B shows a state where the volume of air trapped in the air trap chamber 30-33 is increased to some extent. After the ink flows from the third chamber 11c to the first chamber 11a, the resistance of the first filter 13a interferes with direct ink flow from the first chamber 11a to the second chamber 11b. Thus, the air contained in the ink moves up by its own buoyancy and is trapped at the upper portion of the air trap chamber 30-33. The air trapped there is not discharged by suction force generated when the print head 15 ejects ink. As a result, the air gradually fills the air trap chamber 30-33 and lowers the ink level in the first and second chambers 11a, 11b, as shown in Figs. 14B-14D.

[0101] Even when the ink level falls below the top end of the first filter 13a, the ink is supplied from the first chamber 11a to the second chamber 11b through the first filter 13a. The hole opening's diameter and the area of the first filter 13a are appropriately set to ensure a sufficient ink supply until the ink level falls to the predetermined level.

[0102] In this state, the pressure waves generated in the tube 5a-5d are absorbed by the air trapped at the upper portion of the air trap chamber 30-33.

[0103] Shortly before an insufficient supply of ink to the ink jet head 15 occurs, the thermistor 18a starts being exposed above the ink surface. As described above, the purge device 6 conducts the purging operation when the resistance of thermistor 18a changes. During the purging operation, a high suction force is applied to the second chamber 11b, and thus the ink, when passing through the first filter 13a, undergoes extremely high resistance to the ink flow. As a result, the ink flow passing through the opening 13e (above the first filter 13a) between the first and second chambers 11a, 11b is generated, thereby discharging the air trapped in the air trap chamber 30-33. Then, when the ink level reaches the second predetermined level, the second thermistor 18b detects the ink level and the purging operation is stopped. Thus, the air in the air trap chamber 30-33 is not discharged completely, and the

remaining air can absorb the pressure waves generated even immediately after the purging operation.

[0104] As described above, the pressure waves generated in the ink passage are guided along the guide wall 311d1 and are absorbed by the air trapped at the upper portion of the air trap chamber 30-33, instead of propagating to the corresponding print head 15. Accordingly, the meniscus formed in the ink nozzle is maintained to accomplish constant ink ejection, and high print quality can be ensured.

[0105] An eighth embodiment of the invention will be described with reference to Figs. 15 -17. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations thereof will be omitted.

[0106] Referring to Fig. 15, a wall 11k divides the lower portion of each air trap chamber 30–33 into the first and second chambers 11a, 11b at such a position that the volume of the second chamber 11b is smaller than that of the first chamber 11a or about half of the first chamber 11a. The wall 11k extends vertically, parallel to the body 3b of the print head unit 3. The wall 11k is placed parallel to the moving direction A of the carriage 3a and the long side of the wall 11k is placed in the vertical direction B of the carriage 3a. The length of the longer side of the wall 11k in direction B is formed shorter than the inner length of the air trap unit 11. The height of the wall 11k is shorter than the length of each air trap chamber 30–33 to form the opening 13e. The opening 13e allows ink to communicate between the first and second chambers 11a, 11b with less resistance. The width of the wall 11k is long enough to extend from side to side of the air trap chamber 30-33, to prevent air introduced into the first chamber 11a from entering into the second chamber 11b. Each air trap chamber 30–33 and the wall 11k are placed in the vertical direction so that air introduced into each air trap chamber 30–33 goes up along the first chamber 11a and is trapped at the top portion of the first chamber 11a because the wall 11k does not allow air to go through the wall 11k. Because the wall 11k is made of a material having wettability to ink, the air is unlikely to stay at the wall 11k but is likely to rise in the first chamber 11a.

[0107] At a lower portion of the wall 11k, a circular ink hole 11k1 is provided to go through the wall 11k. On the side of the first chamber 11a, the ink hole 11k1 is provided with a film 11k2. The film 11k2 is fixed at its lower side to the wall 11k by thermal fusion. The film 11k2 is elastically opened on its upper side to uncover the ink hole 11k1. The film 11k2 is closed to cover the ink hole 11k1 when the purge device 6 generates pressure applied to the film 11k2. Because the film 11k2 is fixed to the wall 11k at its lower side, air is unlikely to stay at the film 11k2.

[0108] Referring to Fig. 16, the air trap unit 11 and the joint member 12 are described. The air trap unit 11 comprises three parts 411d–411f. Each of the parts 411d–411f are formed to have four air trap chambers 30–33, corresponding to the four ink tubes 5a–5d. The parts 411d–411f are made of thermoplastic resin considering various factors, such as moldability, resistance to solvents, resistance to contamination, chip resistance, and wettability to ink.

[0109] The wall 11k is fixed by thermal fusion to the part 411e to operate as the wall 11k for each air trap chamber 30–33. The single wall 11k provides four walls for the air trap chambers 30–33 so that the wall 11k for the four air trap chambers 30–33 is made at once by thermal fusion of the wall 11k to the part 411e.

[0110] The width of the wall 11k corresponds to the total width of the series of the four air trap chambers 30–33 in addition to the fusion areas on both sides. The height of the wall 11k corresponds to a height of the first filter to cover a predetermined lower area of each air trap chamber 30–33 in addition to the fusion area. The wall 11k is fixed to the part 411e by thermal fusion in such a position as to provide an opening at the upper portion of the part 411e which comprises the second chamber. Thus the wall 11k is placed so as to divide the air trap chambers 30 – 33 into the first chambers 11a and the second chambers 11b.

[0111] The wall 11k is provided with ink holes 11k1 and films 11k2 corresponding to the air trap chambers 30–33.

[0112] Referring to Figs. 17A – 17F, the ink flow pattern and the condition of trapped air will be described. Fig. 17A shows an initial state of the air trap unit 11 immediately after the purging operation. In Fig. 17A, as the ink is consumed at the print heads 15, ink supplied from the ink tank 4 to the first chamber 11a goes into the second chamber 11b over the wall 11k through the opening portion 13e where the wall 11k is not provided, and through the ink hole 11k1.

[0113] In Fig. 17B, when a small amount of air goes into the first chamber 11a of each air trap chamber 30–33, air is unlikely to stick to the wall 11k because of good ink wettability of the wall 11k. Because each air trap chamber 30–33 is placed in the vertical direction, air rises by its buoyancy along the ink flow.

[0114] The inner wall of the first chamber 11a is formed of a material having less ink wettability as compared with the inner wall of the second chamber 11b so that air stays in the first chamber 11a rather than the second chamber 11b. When the volume of air trapped in the chambers 11a, 11b is relatively small, the opening 13e between the first chamber 11a and the second chamber 11b is not blocked by the trapped air. The ink supplied to the first

chamber 11a flows into the second chamber 11b through the opening 13e. The speed of the ink flow directed to the print head 15 or the suction force applied to the ink is not fast enough to push the trapped air out from the chambers 11a, 11b.

[0115] In Fig. 17C, the trapped air becomes large enough to block the opening 13e between the first and second chambers 11a, 11b. The ink supplied to the first chamber 11a is blocked and cannot pass into the second chamber 11b through the opening 13e. Once the opening 13e is blocked by the trapped air, the ink starts passing through the ink hole 11k1 of the wall 11k, as shown in Fig. 17C. The film 11k2 is set to be strong enough to remain open against the ink flow going through the ink hole 11k1.

[0116] In Fig. 17D, the volume of the trapped air becomes larger and pushes the ink level down in the chambers 11a, 11b. The ink level goes below the ink hole 11k and the ink is not supplied to the print head 15.

[0117] In Fig. 17E, the purging operation is conducted by the purge device 6 to discharge the trapped air. During the purging operation, because a strong suction force is applied to the second chamber 11b, the resistance to the ink flow going through the ink hole 11k1 becomes very large. Because pressure is applied to the film 11k2 toward the print head 15, the film 11k2 is moved to close the ink hole 11k1. By closing the ink hole 11k1 by the film 11k2, ink in the first chamber 11a is not allowed to pass into the second chamber 11b through the ink hole 11k1. Thus a strong ink flow passing through the opening 13e between the first and second chambers 11a, 11b is generated to discharge the trapped air in each air trap chamber 30–33 to the outside. The first and second chambers 11a, 11b are refilled with ink as shown in Fig. 17F.

[0118] In the above embodiment, the film 11k2 provided with the wall 11k1 acts as a valve member in the air trap unit 11. Air generated in the ink passage, such as the tube 5a–5d, the joint member 12, and the print head 15, is trapped in each air trap chamber 30–33, and the trapped air is purged by the purge device 6 to recover the function of each air trap chamber 30–33. The purging operation is conducted when the thermistor 18 detects a need for the purging operation. The purge device 6 conducts the purging operation efficiently and saves ink consumption.

[0119] A ninth embodiment of the invention will be described with reference to Figs. 18A – 18C. In this embodiment, the film 11k2 in the eighth embodiment is replaced with a valve 11k3. The parts identical to the counterparts of the previously explained embodiments will be assigned the same reference numerals and explanations thereof will be omitted.

[0120] Referring to Fig. 18A, the valve 11k3 is formed of an elastic material into a shape of umbrella. A shaft 11k7 of the umbrella valve 11k3 is slidably inserted into a hole 11k5 that is located at the center between ink holes 11k4 provided at the lower portion of the wall 11k. The valve 11k3 is supported by the hole 11k5 so that the valve 11k3 slides perpendicularly to the wall 11k. The umbrella 11k8 is disposed in the first chamber 11a.

[0121] Referring to Fig. 18B, the umbrella 11k8 of the valve 11k3 is provided with holes 11k6. The umbrella 11k8 is of a cone shape or a dome shape to cover the holes 11k4. The center of the umbrella 11k8 moves toward the wall 11k and the outer edge of the umbrella 11k8 slides on the wall 11k. The holes 11k6 of the umbrella 11k8 are placed so as to not face the ink holes 11k4 when the center of the umbrella 11k8 contacts the wall 11k. The holes 11k6 are closed by the wall 11k, and the ink holes 11k4 are closed by the umbrella 11k8 of the valve 11k3.

[0122] The ink flow, when the print head 15 performs printing, is not fast enough to push the umbrella 11k8 to close. The ink flows from the first chamber 11a through the holes 11k6 and ink holes 11k4 to the second chamber 11b.

[0123] Fig. 18C shows the valve 11k3 during the purging operation by the purge device 6. When the purge device 6 conducts the purging operation, a strong suction force is applied to the second chamber 11b. A resistance to the ink at the ink hole 11k4 is very high and pressure is applied to the valve 11k3 toward the print head 15. The center of the valve 11k3 moves toward the wall 11k, so that the holes 11k6 are closed by the wall 11k and the ink holes 11k4 are closed by the umbrella 11k3. The ink is prohibited from going from the first chamber 11a to the second chamber 11b through the holes 11k4. When the purge device conducts the purging operation, a strong ink flow is generated to pass through the portion connecting the first and second chambers 11a, 11b which corresponds to the opening 13e where the top portion of the wall 11f is not provided. Air trapped in each air trap chamber 30-33 is discharged by the ink flow. Thus, air generated in the ink passage, such as the tube 5a-5d, the joint member 12, and the print head 15, is trapped in each air trap chamber 30-33 and the trapped air is discharged by the purge device 6 to recover the function of each air trap chamber 30-33.

[0124] A tenth embodiment of the invention will be described with reference to Figs. 19A and 19B. In this embodiment, the film 11k2 in the eighth embodiment is replaced with a floating member, such as a floating ball 11k9. The parts identical to the counterparts of the previously explained embodiments will be assigned the same reference numerals and explanations thereof will be omitted.

[0125] Referring to Fig. 19A, an ink hole 11k10 is provided to pass ink therethrough. On the side of the first chamber 11a, a room 11k11 defined by a housing 11k12 is provided. In the room 11k11 the ball 11k9 is installed. The ball 11k9 is larger than the hole 11k10 and is made of a material whose gravity is lighter than that of ink. The ball 11k9 floats in the ink to open the hole 11k10. When the print head 15 performs printing, an ink flow is generated, however, the ink flow is not strong enough to move the ball 11k9 to close the hole 11k10.

[0126] Referring Fig. 19B, when the purge device 6 conducts the purging operation, a strong suction force is generated in the second chamber 11b. A large resistance is applied to ink going through the ink hole 11k10, so that the ball 11k9 is moved to close the ink hole 11k10. When the purge device 6 conducts the purging operation, a strong ink flow is generated to pass through a portion connecting the first and second chambers 11a, 11b which corresponds to a portion where the opening 13e of the top portion of the wall 11f is provided. Air trapped in the air trap chambers 30-33 is discharged by the ink flow. Thus, air generated in the ink passage, such as the tubes 5a-5d, the joint member 12, and the print head 15, is trapped in each air trap chamber 30-33 when the print head 15 performs printing. The trapped air is discharged by the purge device 6 in order to recover the function of each air trap chamber 30-33.

[0127] An eleventh embodiment of the invention will be described with reference to Figs. 21 - 24. The parts identical to the counterparts of the first embodiment will be assigned the same reference numerals and explanations will be omitted.

[0128] Referring to Fig. 20, the carriage 3a is provided with a body 3b for accommodating an air trap unit 11 and a joint member 12. The air trap unit 11 includes the four air trap chambers 30-33 that trap air generated in the ink passage while ink is supplied from the corresponding ink tanks 4a-4d. Each air trap chamber 30-33 has an inner convex or upwardly-curved top surface 30a-33a. The air generated in the ink passage is trapped in the top portions of the air trap chambers 30-33 along the curved top surfaces thereof.

[0129] Referring to Fig. 21, the first chamber 11a is separated by the first filter 13a from the second chamber 11b. The first chamber 11a is located on the side of the ink tank 4, upstream of the ink passage. The first filter 13a separating the two chambers 11a, 11b is provided so as to form the opening 13e at an upper portion of each air trap chamber 30-33, so that the first and second chambers 11a, 11b are fluidly communicated. An inner top surface 511d1 and an inner side surface 511d2 of the first chamber 11a are connected to form a curved corner 511d3. In addition, the first and second chambers 11a, 11b are connected so as

to align each top portion of the chambers 11a, 11b. The ink supplied from the ink tank 4a-4d through the corresponding ink tube 5a-5d is introduced into the first chamber 11a through an ink inlet 23 formed at a bottom portion of the first chamber 11a. The ink introduced into the first chamber 11a is supplied to the second chamber 11b through the first filter 13a or the opening 13e provided above the first filter 13a, as will be described in more detail below with reference to Figs. 23A through 23F. The air flowing into the first chamber 11a, together with the ink, rises by its buoyancy along the curved corner 511d3 of the air trap chamber 30-33 and is trapped at the upper portion of the first chamber 11a. As the amount of the trapped air becomes large, the air is spread over the upper portions of both of the first and second chambers 11a, 11b by the ink flow and the upper portion of each air trap chamber 30-33 is filled with the trapped air.

[0130] The second chamber 11b is fluidically connected to the first chamber 11a, so as to align the inner top surface 511e1 of the second chamber 11b with the inner top surface 511d1 of the first chamber 11a. The second chamber 11b has a tapered inner side surface 511f2 gradually becoming wider toward the bottom of the chamber 11b. The inner top surface 511e1 and the inner side surface 511f2 of the second chamber 11b are connected to form a curved corner 511e3. This structure enables the ink or trapped air to flow smoothly from the first chamber 11a to the second chamber 11b. Further, the trapped air is smoothly discharged by the purging operation, without stagnating at the curved corner 511e3 of the second chamber 11b.

[0131] As shown in Fig. 22, the air trap unit 11 includes three parts 511d-511f. The part 511d is provided with the four first chambers 11a divided by the partitions 11h, as shown in Fig. 20. The part 511e has four openings as the consecutive four second chambers 11b. The part 511f has four recessed portions corresponding to the four openings of the part 511e and forms the four second chambers 11b together with the part 511e.

[0132] Referring to Figs. 23A – 23F, ink flow patterns and the condition of the trapped air will be described. Fig. 23A shows an initial condition of the air trap unit 11 immediately after the purging operation. In Fig. 23A, as ink is consumed at the print head 15, ink supplied from the ink tank 4 to the first chamber 11a goes into the second chamber 11b over the first filter 13a or through the opening 13e where the first filter 13a is not provided. The opening 13e has less resistance to the ink flow than the first filter 13a to promote such ink flow.

[0133] In Fig. 23B, when a small amount of air enters the first chamber 11a of the air trap chamber 30-33, air is unlikely to stick to the first filter 13a because of good ink

wettability of the first filter 13a. In addition, because the air trap chamber 30-33 is placed in the vertical direction, air rises by its buoyancy along the ink current flow. Further, because the openings of the first filter 13a are smaller than the size of air bubbles, the air bubbles do not pass through the openings of the filter 13a, but rise along the ink flow.

[0134] The inner wall of the first chamber 11a is formed with material having less ink wettability compared to the inner wall of the second chamber 11b, so that the air generally stays in the first chamber 11a rather than the second chamber 11b. When the volume of air trapped in the chambers 11a, 11b is relatively small, the opening 13e between the first chamber 11a and the second chamber 11b is not blocked by the trapped air. The ink supplied into the first chamber 11a flows into the second chamber 11b through the opening 13e. The speed of the ink flow supplied to the print head 15 or suction force of the ink during printing is not fast enough to push the trapped air from the chambers 11a, 11b.

[0135] In Fig. 23C, the trapped air becomes large enough to block the opening 13e between the first and second chambers 11a, 11b. The ink supplied to the first chamber 11a is blocked from passing into the second chamber 11b through the opening 13e. Once the opening 13e is closed by the trapped air, ink passes through the first filter 13a, as shown in Fig. 23C.

[0136] In Fig. 23D, the volume of the trapped air becomes larger, pushing the level of ink surface in the chambers 11a, 11b down. The area of the first filter 13a and its openings are set to keep supplying ink even if the level of the ink surface lowers to a predetermined level.

[0137] In Fig. 23E, the volume of the trapped air becomes large enough to fill the second chamber 11b. In this condition, ink is not supplied to the print head 15.

[0138] In Fig. 23F, the purging operation is conducted by the purge device 6, so that the trapped air is discharged. During the purging operation, because a strong suction force is applied to the second chamber 11b, the resistance to the ink flow passing through the first filter 13a becomes very large. Thus, a strong ink flow passing through the opening 13e between the first and second chambers 11a, 11b is generated to discharge the trapped air in the air trap chamber 30-33 to the outside. Ink is refilled into the first and second chambers 11a, 11b, similar to the initial condition shown in Fig. 23A.

[0139] Referring to Fig. 24, an air flow in the air trap chamber 30-33 is described below. Arrows in Fig. 24 show the flow of the air bubbles in the air trap chamber 30-33. Each of the air trap chambers 30-33 includes the ink inlet 23 through which ink is supplied from the corresponding ink tanks 4a-4d, the first filter 13a that separates the two chambers

11a, 11b and forms the opening 13e at the upper portion of the air trap chamber 30-33, and an ink outlet 24 (not shown in Fig. 24) from which the ink flows to the print head 15. The inner top surface 511d1 of the air trap chamber 30-33 is convex or curved upwardly. The second chamber 11b is fluidically connected to the first chamber 11a, so as to align the inner top surface 511e1 of the second chamber 11b with the inner top surface 511d1 of the first chamber 11a. The inner top surface 511e1 of the second chamber 11b is connected to the tapered inner side surface 511f2, which gradually becomes wider toward the bottom of the chamber 11b, so as to form the curved corner 511e3.

[0140] Ink supplied from the ink tank 4a-4d flows into the air trap chamber 30-33 through the ink inlet 23. The flow of the ink introduced into the first chamber 11a is blocked by the first filter 13a. The ink in the first chamber 11a flows into the second chamber 11b, through the opening 13e provided at the upper portion of the first filter 13a, and then into the print heads 15 through the ink outlet 24. As air is introduced into the ink tube 5a–5d, the air is delivered to the first chamber 11a together with ink supplied from the ink tank 4 through the ink tube 5a-5d. The air, in the ink, supplied to the first chamber 11a rises by its buoyancy to the upper portion of the air trap chamber 30-33, as shown by arrows with dotted lines in Fig. 24. The air goes up along inner surfaces 511d4, 511d5 of the first chamber 11a and is trapped in the inner top surface 511d1 of the first chamber 11a. Then, the air is carried by the ink flow into the second chamber 11b whose inner top surface 511e1 is aligned with the inner top surface 511d1 of the first chamber 11a.

[0141] The air trapped in the air trap chamber 30-33 is discharged from the ink outlet 24 by the purging operation. The upper corner 511d3 of the first chamber 11a, which is provided on the inner surface thereof on the side of the ink tank 4, is curved. The second chamber 11b is fluidically connected to the first chamber 11a, so as to align the inner top surface 511e1 of the second chamber 11b with the inner top surface 511d1 of the first chamber 11a. The inner top surface 511e1 of the second chamber 11b is connected to the tapered inner side surface 511f2, which gradually becomes wider toward the bottom of the chamber 11b, so as to form the curved corner 511e3. With this structure, stagnation points do not occur at the corners 511d3, 511e3 or the top inner surfaces 511d1, 511e1 of the air trap chamber 30-33, when air trapped in the chamber 30-33 is sucked during the purging operation from the first chamber 11a, toward the bottom of the second chamber 11b. Therefore, the air trapped in the air trap chamber 30-33 is discharged smoothly by the purging operation without leaving the air therein.

[0142] Although the inner top surface 511d1 of the first chamber 11a is convex or

curved upwardly in the above-described eleventh embodiment, for example, the inner top surface may be formed to have a shape of triangle or trapezoid rising upwardly. Similar to the first chamber 11a having the inner top surface 511d1 in the eleventh embodiment, the triangular or trapezoidal chamber can trap air along an angled surface thereof, and the air can be discharged smoothly. The inner top surface 511d1 of the first chamber 11a is parallel to the bottom surface of the air trap unit 11. However, the air trap unit 11 may have an inner top surface angled upwardly toward the ink flow direction, that is, toward the second chamber 11b. Because air is trapped along the angled inner top surface, the air is discharged smoothly.

[0143] It should be understood that the invention is not limited in its application to the details of structure and arrangement of parts illustrated in the accompanying drawings. The invention is capable of other embodiments and of being practiced or performed in various ways without departing from the technical idea thereof, based on existing and well-known techniques among those skilled in the art.